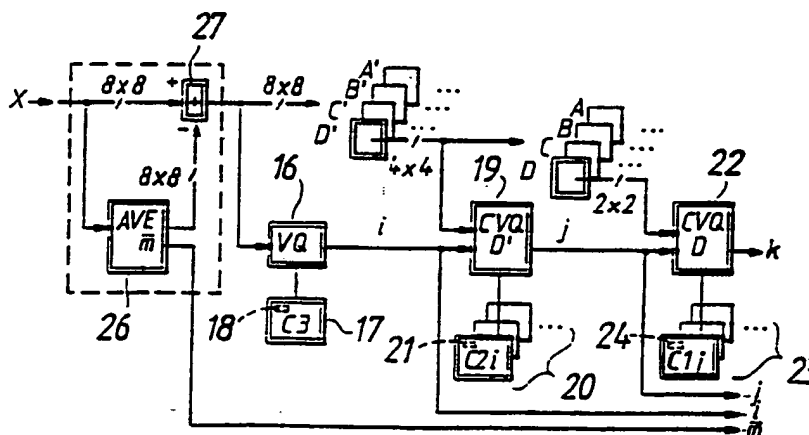




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : H04N 7/137	A1	(11) International Publication Number: WO 93/23956 (43) International Publication Date: 25 November 1993 (25.11.93)
(21) International Application Number: PCT/FI93/00203 (22) International Filing Date: 11 May 1993 (11.05.93) (30) Priority data: 922300 20 May 1992 (20.05.92) FI (71) Applicant (for all designated States except US): VALTION TEKNIILLINEN TUTKIMUSKESKUS [FI/FI]; Vuorimiehentie 5, FIN-02150 Espoo (FI). (72) Inventors; and (75) Inventors/Applicants (for US only): VIRTAMO, Jorma [FI/FI]; Itätuulentie 5 C 55, FIN-02100 Espoo (FI). VALLI, Seppo [FI/FI]; Rauduntie 25 A, FIN-02130 Espoo (FI). (74) Agent: PAPULA REIN LAHTELA OY; Box 981, Salomonkatu 17 B, FIN-00101 Helsinki (FI).	(81) Designated States: AU, CA, JP, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published With international search report.	

(54) Title: METHOD FOR IMAGE COMPRESSION CODING IN AN IMAGE TRANSMISSION SYSTEM



(57) Abstract

The invention relates to an image compression coding method of a digital image transmission system. The method utilizes a known vector quantization process. In the method of the invention, at the transmitting end the block (13) to be coded is divided into quadrants (14); each quadrant is subjected to vector quantization in a sub-coder (19), utilizing a classified codebook (20), the class thereof being defined on the basis of the vector index (i) of the original block and the quadrant label (A', B', C', D') of the sub-block; the vector index (j) of the sub-block with respect to this classified code book (20) is transmitted to the receiving end; at the receiving end, there is utilized a classified codebook which is chosen on the basis of the transmitted vector index (i) of the original block and the quadrant label (A', B', C', D') of the sub-block; at the receiving end, the chosen classified codebook, which is identical with the classified codebook at the transmitting end, the code vector in question is looked up on the basis of the vector index of the transmitted sub-block, so that a reconstruction is obtained for the sub-block. When designing each classified codebook, the utilized training image material is that part of the original training image set which receives a class index corresponding to the particular class of the codebook, when the above described method is applied to the training image set itself.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FR	France	MR	Mauritania
AU	Australia	GA	Gabon	MW	Malawi
BB	Barbados	GB	United Kingdom	NL	Netherlands
BE	Belgium	GN	Guinea	NO	Norway
BF	Burkina Faso	GR	Greece	NZ	New Zealand
BG	Bulgaria	HU	Hungary	PL	Poland
BJ	Benin	IE	Ireland	PT	Portugal
BR	Brazil	IT	Italy	RO	Romania
CA	Canada	JP	Japan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo	KR	Republic of Korea	SE	Sweden
CH	Switzerland	KZ	Kazakhstan	SK	Slovak Republic
CI	Côte d'Ivoire	LI	Liechtenstein	SN	Senegal
CM	Cameroon	LK	Sri Lanka	SU	Soviet Union
CS	Czechoslovakia	LU	Luxembourg	TD	Chad
CZ	Czech Republic	MC	Monaco	TG	Togo
DE	Germany	MG	Madagascar	UA	Ukraine
DK	Denmark	ML	Mali	US	United States of America
ES	Spain	MN	Mongolia	VN	Viet Nam
FI	Finland				

METHOD FOR IMAGE COMPRESSION CODING IN AN IMAGE TRANSMISSION SYSTEM

The invention relates to the method defined in
5. the introductory section of patent claim 1 for image compression coding in an image transmission system, particularly for realizing compression coding in a digital image transmission system.

In the prior art there is known a vector quantization (VQ) method for image compression coding. The
10 VQ method is discussed extensively in the reference publication /1/. In the VQ process, the image to be transmitted is divided into blocks, and for each block, there is searched in the codebook a codevector that
15 best corresponds to the particular block. The vector index of this codevector, i.e. its location in the codebook, is transmitted. At the receiving end, the said vector is looked up in a corresponding codebook on the basis of the vector index of the codevector. The
20 transmitted image is reconstructed, block by block, by means of the said codevectors. The codebook is designed beforehand by using training images and a suitable codebook design algorithm. In a corresponding fashion, the training images are divided down to the used block
25 size while creating the codebook.

A drawback of the said VQ method is its limited block size. The efficiency of the process stems from the fact that all statistical dependencies within the block are taken into account. The correlations over
30 the block boundaries remain unexploited. In standard vector quantization, large scale correlations can be utilized to achieve a higher compression only by using a larger block size. This unfortunately leads to an exponential growth of the codebook size for a fixed
35 picture quality. The number of comparisons to find the best codevector in the codebook also grows respectively. Therefore VQ becomes computationally unpractical

with large block sizes. Usually the block size is limited to the order of 4×4 pixels, which leaves a lot of statistical dependencies beyond the reach of the method.

5 The problem with large block size in vector quantization is twofold. On the one hand, the sheer size of the codebook becomes a memory storage problem. On the other hand, the computing time to find the best codevector may become excessive. Several applications
10 of the VQ method have been developed to overcome these problems.

 In a modified vector quantization process, the tree search VQ (TSVQ), the computing time problem is addressed by using a binary search procedure to find
15 the best codevector. In image quality terms, TSVQ works slightly worse than the standard VQ.

 Another modified vector quantization process, the cascaded VQ, represents a direct attack on the main problem of standard VQ, i.e. the problem with block
20 size. In this method, a relatively large block size is chosen in order to capture the large scale correlations. However, the employed codebooks are reasonable in size and thus easily manageable. To compensate for the unavoidable lack of accuracy, the method is applied
25 in successive coding stages. At each of the later stages, the coding error of the previous stage is quantized. A drawback is that any correlations that may exist between successive codevectors are lost.

 In a third modified vector quantization process, which is a refinement of the cascaded VQ, the
30 block size is changed when proceeding from the first coding stage to the next. The coding error, which contains the fine details of the image, is coded using sub-blocks. By using this method, the number of such
35 codevectors in the codebook that are needed to represent the small scale details can be drastically brought down with a small block size.

In a fourth modified vector quantization process, the classified VQ, the blocks are classified prior to coding. The classification is based on local image features. This improves especially the representation of edges, which is found to be rather poor in standard VQ. For each block class there is a separate codebook. A reasonably small codebook will suffice since the image blocks in the same class have more or less similar character. Inter block correlations can be used to some extent, if the classification process is not restricted inside the block boundaries.

In a fifth modified vector quantization process, the so called finite-state VQ (FSVQ), inter-block correlations are utilized on the basis of the above mentioned classification. Thus the class of the block is defined with the aid of the larger image context. The image context includes a number of neighbouring blocks that have already been coded and transmitted. A drawback is, that classification errors may reduce the quality of the coding output of the edges represented in the image.

A sixth modified vector quantization process, the so called address VQ, utilizes the joint distribution of the vector indices of a group of blocks. Special codewords saved in a so called address codebook are reserved for the most probable combinations of vector indices. For all other combinations, the vector indices are transmitted separately. In updating the address codebook, there are utilized the detected joint probabilities of different combinations of vector indices between neighbouring blocks. The address codebook is formed as a distortionless post coding scheme on top of standard VQ, and gives the same picture quality at a lower bit rate than standard VQ.

The object of the present invention is to introduce a new method for image compression coding in an image transmission system, whereby the block size

problem can be avoided at least to some extent. Another object of the invention is to achieve a new compression coding method, whereby problems connected to modified vector quantization processes can be overcome.

5 The method of the invention is characterized by the novel features enlisted in patent claim 1.

 In the method of the invention for image compression coding in an image transmission system, particularly for carrying out image compression in a digital image transmission system, there is utilized a VQ process where the image is divided into blocks at the transmitting end, and for each block there is searched in the codebook a best corresponding codevector, and the vector index of this codevector, i.e. its location
10 in the codebook, is transmitted to the receiving end, where the respective codevector is looked up in an identical codebook on the basis of the index, and the image is reconstructed block by block with the aid of the codevectors; the said codebook is designed beforehand by means of training images, which images are in
15 similar fashion divided into blocks according to the employed block size. In the method of the invention
20 - at the receiving end, the block to be coded is divided into quadrants or sub-blocks;
25 - each sub-block is subjected to vector quantization by a classified codebook, and the class thereof is defined on the basis of the vector index of the original block and the quadrant label of the sub-block;
 - the vector index of the sub-block, with respect to
30 this classified codebook, is transmitted to the receiving end;
 - at the receiving end, there is utilized a classified codebook which is chosen on the basis of the vector index of the transmitted original block and the quadrant
35 label of the sub-block;
 - at the receiving end, the codevector in question is looked up in the chosen classified codebook which is

identical with the classified codebook at the transmitting end, on the basis of the vector index of the transmitted sub-block, so that a reconstruction is obtained for the sub-block; and in the method of the
5 invention, while creating each classified codebook, the employed training image material is that part of the original training image set which belongs to the respective class, i.e. those quadrant-size sub-blocks of the training image set which receive a class index
10 corresponding to the particular class of the codebook, when the above described method is applied to the training image set itself.

In the method of the invention, vector quantization is applied successively, starting with a suitably chosen block size and by proceeding to its quadrants. Vector quantization carried out at the latter
15 stage utilizes information that is already coded using a larger block size by means of the so called classification. The employed defining index of a class is the vector index obtained from the first quantization, as
20 well as the quadrant label.

In an advanced embodiment of the invention, a quadrant, i.e. a sub-block, is further divided into quadrant sub-blocks, and these further into smaller and
25 smaller sub-blocks by following the same principle, so that each quadrant and sub-block is coded with a classified codebook, where the classifiers are the vector indices of all the parent blocks of the said quadrant or sub-block whereto the quadrant or sub-block to be
30 coded belongs, as well as the quadrant labels of the concerned quadrant or sub-block and the said parent blocks, and where the classified codebooks are designed beforehand in the above described fashion.

In the above described method vector quantization is applied by proceeding from a suitably chosen
35 block, i.e. block size, to its quadrants, then further down to their quadrants and so on, as far as the desi-

red depth. At each block level, there is carried out vector quantization in which the information that was already coded in the larger block size is utilized by means of classification; the defining indices of the class are vector indices obtained as results of earlier quantizations and corresponding quadrant labels. Coding is continued down to the desired depth, as far as the bitrate of the employed transmission channel allows, or until the picture quality is otherwise sufficient. In the hierarchically classified vector quantization process of the invention, the image is thus sharpened step by step, by the aid of relatively little extra information.

In another advanced embodiment of the invention, prior to the characteristic quadrant division of the image block, the image block is reconstructed on the basis of the information coded so far, and there is formed a difference between the original image block and the reconstructed image block, which difference block thus contains the coding errors of the previously performed coding step, and the method of the invention is applied to the thus created difference block instead of the image block. The difference block is divided into quadrant blocks, which are vector quantized by utilizing the information that was already coded in larger block size by means of classification. The classified codebooks are designed, according to the method of the invention, by using as training material those sub-blocks of the difference block that obtain corresponding class indices as the considered sub-block of the difference block, when the method is applied to the training image set itself.

An advantage of the above described embodiment is that the difference signal is more compact, i.e. the values contained in the difference block fluctuate within a more limited range than the values of the image signal proper, which makes coding more efficient.

However, it is pointed out that the information coded with larger block size gives a poorer description of the features of the difference block, and this decreases the advantage and coding efficiency that are characteristic of the method of the invention. The realization of an application that codes the difference signal also is somewhat more complicated.

In another advanced embodiment of the method, at the first block level the coding is made more effective by separating, prior to the coding, the mean value of the gray level values of the pixels contained in each block of the image, and by transmitting the mean value separately from the transmitting end to the receiving end.

In another advanced embodiment of the method, the image is subjected to low pass filtering at the transmitting end, and the filtered image is separately transmitted to the receiving end, and one of the above described methods or an application thereof is applied only to the high-frequency component of the image, i.e. to the difference image of the original image and the low pass filtered image. The low-frequency component contains the most important part of the image, and little information and little channel capacity are needed for its transmission. Thus the blockiness of the image is reduced, particularly in "smooth" areas, i.e. in areas containing few changes.

In another advanced embodiment of the method, the sizes of the codebooks used in coding sub-blocks and possibly subsequent smaller sub-blocks are varied case by case, on the basis of the image content of the coded block, so that in coding blocks with few details, there are used smaller codebooks than in coding blocks with a lot of details, in which case the information of the size of the codebook is transmitted as extra information.

In another advanced embodiment of the method,

the sizes of the codebooks used in coding sub-blocks and possibly subsequent smaller sub-blocks are varied on the basis of the image content of the coded block, so that in coding blocks with few details, there are
5 used smaller codebooks than in coding blocks with a lot of details, and the size of the codebook is defined permanently on the basis of the class index. In this case additional information is not transmitted, but the choice takes place automatically.

10 As for the advantages of the invention, let us point out the following. The method of the invention utilizes the large-scale correlations of the image. This is based on the suitably chosen large initial block size. With respect to accuracy, the process can
15 be modified in a desired fashion, because the image is coded in several stages starting with a relatively large block, which is subsequently divided into smaller and smaller sub-blocks. The more sub-blocks are coded, the higher the accuracy of the image in the respective
20 area becomes. Another advantage of the invention is that it is extremely efficient and the subjective quality of the coded images is good. Yet another advantage of the invention is that the method is fairly easy to apply, and low transmission rates can be achieved.

25 The invention and its further advantages are explained below, with reference to the appended drawing, where
figure 1 is a schematical illustration of a vector coding method; and
30 figures 2a, 2b and 2c are schematical illustrations of how an image block is divided into sub-blocks in the image compression coding method of the invention;
figure 3 is a block diagram illustrating a coder according to the compression coding method of the invention;
35 figure 4 respectively illustrates a decoder; and
figure 5 illustrates another coder according to the compression coding method of the invention.

The principle of vector quantization is illustrated in the block diagram of figure 1. An image 1, obtained from a camera such as a video camera, is recorded in the image memory 2. The image 1 is composed of $n \times m$ pixels ($n, m = \text{integers}$). By means of a suitable processing unit 3, the image 1 stored in the image memory 2 is divided into blocks 4, i.e. vectors. A typical size for the block 4 is 4×4 pixels. Each pixel contains the gray tone information on a predetermined gray scale. In the processing unit 3, for each block 4 of the image there is searched the best corresponding codevector 7a from the codebook 6 stored in the codebook memory 5. The codebook 6 is designed beforehand by means of training images and by using a suitable codebook design algorithm, for instance the so called LBG algorithm /2/. The order number a of the codevector 7a in the codebook 6, i.e. its vector index, is transmitted through the transmission channel 8 from the transmitting unit A to the receiving unit B.

The image is reconstructed in the image memory 9 of the receiving unit B by looking up, by means of the image processing unit 10, the codevector 7a corresponding to the vector index a in the codebook 12 recorded in the memory 11 of the codebook. When all of the blocks 4' belonging to the image 1' are compiled in the image memory 9 as codevectors, the image can be displayed on a monitor.

The method of the invention for image compression coding in an image transmission system utilizes the above described vector quantization process. This is illustrated by the block diagram of figure 3. A larger block size than in standard VQ is chosen. Typically the size of the block 13 (cf. figure 2a) is for instance 8×8 pixels. At the first stage, the block is coded in the first sub-coder 16 by means of a first codebook 17 with a relatively small number of codevectors. The number of the first codevectors 18 is for

instance 64. The size of the codevector 18 corresponds to the size of the block 13 and is for example 8 x 8 pixels. This means that at this coding stage, the image can be figured out only roughly, i.e. only the basic
5 features contained in the low-frequency components of the image can be identified.

At the following stage, the blocks 13 are divided into quadrants 14, i.e. into sub-blocks 14A', 14B', 14C' and 14D', as is illustrated in figure 2b.
10 Thus the size of each sub-block 14 is for instance 4 x 4 pixels. In the second sub-coder 19 each sub-block 14 is coded by means of the second codebook 20, which is compiled of a number of classified codebooks, by using as classifiers the vector index i of the original block
15 13 and the quadrant label A', B', C' and D' of the sub-block 14, i.e. its location inside the original block 13. Accordingly, in coding the sub-block 14, there is utilized, from among the classified codebooks 20, that particular codebook which is defined by the
20 label of each quadrant 14 of the original block 13, and by the vector index i of each original block 13. The first codevector 18 found on the basis of the original block 13 defines the rough features of the image in each block thereof, and the second codevectors 21 from
25 the second codebooks 20 sharpen the image as for the sub-blocks 14. The size of the second codevector 21 corresponds to the size of the sub-block 14 and is for instance 4 x 4 pixels. Thus a relatively limited amount of additional information is needed for coding the fine
30 details, because a relatively small number of codevectors is sufficient in the classified codebook 20.

The method of the invention can be further applied by assuming at the following stage each of the sub-blocks 14A', 14B', 14C', and 14D', obtained in the
35 above described coding process, as a new initial block and by submitting each quadrant 15A, 15B, 15C and 15D of the sub-block 14 to the same procedure (figure 2c).

Each of these new sub-blocks 15 thus contains for instance 2 x 2 pixels. In the third sub-coder 22, the small sub-blocks 15 are coded by utilizing the VQ process, so that in the third codebook 23, which is composed of a number of classified codebooks, there is looked up a suitable third codevector 24. The respective vector indices i, j of the original block 13 (e.g. 8 x 8 pixels) and of its sub-block 14 (e.g. 4 x 4 pixels) whereto the new sub-blocks 15A, 15B, 15C and 15D belong, together with the quadrant labels of the sub-block 15 and the sub-block 14, define which of the said codebooks 23 is used in order to find the codevector 24. These class indices contain all the information that is so far extracted from the image content of the block. Each third codebook 23 contains a relatively small number of codevectors, and their number is generally more limited than the size of the codebooks 17, 20 used at the preceding coding level. Thus there is realized a hierarchical coding procedure, where the original relatively large image blocks can be represented step by step with growing accuracy.

The image that is coded and further transmitted at the transmitting end, is at the receiving end decoded by a simple reversed decoding process, which is illustrated as a block diagram in figure 4. The combined codebook 24 of the receiving end contains codebooks that are identical with the codebooks 17, 20, 22 of the transmitting end. For the actual compilation of the image, there are used the codevectors 24 of the lowest level codebooks 23. The image is compiled block by block in the reconstruction unit 25 and is transmitted further in order to be reconstructed of blocks into an image in a previously known fashion. Each codevector 23 is completely defined by its own vector index k in the particular codebook denoted by the classifying vector index j, i . It is pointed out that only hierarchical vector indices i, j must be transmitted; the

labels, i.e. location indices of the quadrants, are implied automatically by the synchronism between the coder and the decoder. The vector index which is transmitted at a certain level is shared by all its
5 four sub-blocks and all their descendants.

Figures 3 and 4 illustrate, in blocks marked with dotted lines, how coding and decoding is improved by means of averaging. At the transmitting end (figure 3), at the first block level, the mean value \bar{m} of initial blocks of for instance 8 x 8 pixels is calculated
10 in the averaging unit 26, and is further separated from each transmittable block in the differentiation unit 27. The mean value means the average of the gray tones in the pixels contained by each block. The mean value
15 \bar{m} is transmitted as a digital message to the transmission path and further to the receiving end. The block difference, i.e. the difference blocks, are coded and respectively decoded according to the method of the invention. At the receiving end (figure 4) the block
20 according to the mean value is reconstructed in the mean value block reconstruction unit 30, and it is summed in the summing unit 29 to the difference block in decoded form.

An application of the compression coding method of the invention is illustrated in figure 5. In this
25 application, prior to each quadrant division of the image block, typical of the invention (cf. figures 2a, 2b, 2c), the image block is first reconstructed in the sub-coder 16, 19 on the basis of the information coded so far. The difference between the image block and the
30 reconstructed image block, i.e. the difference block, is formed in the differentiation unit 28, 29. Thus the difference block contains the coding errors of the previous coding stage. Now the method of the invention
35 is applied to the difference block in the fashion described above, instead of the image block. In figure 5, like reference numbers are used of the separate

units of the coder as earlier in connection with figure 3. At the receiving end, the decoding is in principle realized as a reversed operation with respect to the coding process.

5 Averaging can also be applied to the above described method of the invention, as is apparent from figure 5. The averaging unit 26 and the differentiation unit 27 are adjusted to the coding system prior to the coding arrangement proper of the above described process. Decoding is in principle realized in similar
10 fashion as in the application of figure 4.

 In standard VQ, the codebook is designed by using a large number of statistically representative training images. The generally known LBG algorithm can
15 be used while designing the codebook. In the compression coding method of the invention the codebooks 17, 20, 23 are created by proceeding hierarchically, so that while designing each classified codebook, the employed training image material is that part of the original
20 training image material which belongs to the class in question.

 The first codebook 17 for the uppermost level is designed in the standard way by using the whole set of training blocks of the initial block size (e.g. 8 x
25 8 pixels). At the next lower level, each of the codebooks 20 is designed by using blocks of the original training images, which are first quantized with the first codebook and then grouped into different sets according to the resulting vector indices. In each set,
30 the blocks are then divided into four quadrants (i.e. sub-blocks, such as 4 x 4 pixels) to form four separate subsets A', B', C', D'. All of the sub-blocks in the subset A' have the same classifying vector and quadrant indices. The obtained subsets are used as training
35 material for the said codebooks 20.

 The above described process for designing the codebooks can be continued in similar fashion, by sub-

dividing the already created subsets of training images further into smaller subsets by classification with the codebooks already worked out and by a further division into four quadrants. Each new subset is used as a training set for a new codebook at the next lower level.

The following description offers an analytical review of the compression coding method of the invention. Let us first define that the block at the lowest level is called a basic block, and let its size be $N \times N$ pixels. The hierarchical levels of blocks are labeled by the index h . This index h runs from 1 (lowest level) to L (top level). A block at level h ($h = 1, \dots, L$) belongs as a sub-block to a block at the next higher level, $h + 1$. The quadrant in question is denoted by the label α_h , which may take any of the four values A, B, C and D (cf. figure 2).

The coding proceeds in a treelike manner. At level h , the whole chain of previous quantization indices and quadrant labels is: (1)

$$c_h = (i_L; \alpha_{L-1}, i_{L-1}; \dots; \alpha_h)$$

and it forms a composite class index. The block at level h is then vector quantized using the codebook of the class c_h . The resulting index i_h together with the class index c_h defines the composite vector index: (2)

$$k_h = (i_L; \alpha_{L-1}, i_{L-1}; \dots; \alpha_h, i_h),$$

which completely specifies the coding result at this level. This composite vector index of a sub-block, and the quadrant label of a sub-block at the next lower level again function as a classifier c_{h-1} for that lower-level sub-block, and so on.

Let the size of the classified codebook at level h be I_h (i.e. $i_h = 1, \dots, I_h$). Then, $b_h = \log_2(I_h)$ bits are needed to transmit the value of the index i_h .

from the transmitting end through the transmission path to the receiving end. As noted before, the quadrant labels are not transmitted, because they are implied by the synchronism between the coding unit of the transmitting end and the decoding unit of the receiving end. The value of index i_h of a block at the level h is shared by its sub-blocks and all their descendants. Therefore, the bitrate of the whole process down to the lowest level, counted as bits per basic block ($N \times N$ pixels) is: (3)

$$R = b_1 + \frac{1}{4}b_2 + \dots + \frac{1}{4^{L-1}}b_L = \sum_{h=1}^L \frac{1}{4^{h-1}}b_h.$$

Since all the values of the vector indices i_h are not equally probable, the actual information transfer rate can further be reduced by entropy coding. The entropy can be calculated assuming a codeword of length: (4)

$$b_h(k_h) = -\log_2 P(i_h | c_h),$$

is associated to index i_h in class c_h , where $P(i_h | c_h)$ gives the (conditional) probability of the vector index i_h in the class. Note that at each level, the additional information needed to transmit the vector index of a block depends both on the index itself and on the class of the block, i.e. on the whole composite index k_h of that block.

Let k_h be the composite index of a block at the lowest level. The total amount of information for this block is then: (5)

$$R_o(k_1) = b_1(k_1) + \frac{1}{4}b_2(k_2) + \dots + \frac{1}{4^{L-1}}b_L(k_L) = \sum_{h=1}^L \frac{1}{4^{h-1}}b_h(k_h),$$

where k_h now means k_h truncated after level h (cf. equation 2). The average total bit rate (entropy) is then: (6)

$$R_e = \sum_{k_1} P(k_1) R_e(k_1).$$

The probability distribution $P(k_1)$ of the lowest level composite vector indices k_1 may be estimated from their occurrence probabilities in the training set coded by the method.

5 The compression coding method of the invention can be understood as a special classification process inside the initial image blocks (e.g. 8 x 8 pixels), combined with the actual coding phase - i.e. vector quantization of sub-blocks on the lowest level (e.g. 4
10 x 4 or 2 x 2 sub-blocks). The compression coding method of the invention uses previous VQ results in a natural way. There is no need to find any special criterium to separate the different classes.

 The compression coding method of the invention
15 and tree search VQ (TSVQ) have similar features. In TSVQ, successive coding results (branches of the tree) determine the codebook to be used in the next stage. An essential difference in between the method of the invention and the said tree search method is, that in
20 TSVQ the block size is fixed and remains the same through the whole process, whereas the method of the invention makes an extra branching towards smaller and smaller sub-blocks at each stage.

 TSVQ mainly addresses the problem of coding
25 time while still needing a very large codebook for good quality results, i.e. a high-quality image, with larger block sizes. An advantage of the method of the present invention is its speed, which is achieved by coding based on hierarchy levels. Another advantage is that
30 the numbers of the codevectors of the codebooks can be maintained on a reasonable level because of the hierarchically decreasing block sizes employed to define the details of the image. Viewed from a different angle, it

can be said that the compression coding method of the invention is able, for a good outcome, also to utilize large scale correlations within the picture by starting with a larger block size.

5 . In the above specification the invention is described mainly with reference to one preferred application only, but it is naturally clear that the invention can be modified in many ways within the scope of the appended patent claims.

10

References:

/1/ H. Abut, ed., "Vector Quantization", IEEE Press, 1990.

15 /2/ Y. Linde, A. Buzo, R.M. Gray, "An Algorithm for Vector Quantization for Image Coding", IEEE Trans. Comm., vol. COM-28, pp. 2301-2304, 1991.

PATENT CLAIMS

1. A method for image compression coding, particularly for doing compression coding in a digital image transmission system, the said method utilizing a vector quantization process where the image is divided into blocks at the transmitting end, and for each block, there is searched a best corresponding codevector in the codebook, and the vector index, i.e. the codevector's location in the codebook, is transmitted to the receiving end, where on the basis of the index there is looked up in an identical codebook the respective codevector, and the image is reconstructed block by block by utilizing the codevectors, the said codebook being designed beforehand by means of training images, which images are in similar fashion divided into blocks according to the employed block size, characterized in that method:
- at the transmitting end, the block to be coded is divided into quadrants, i.e. sub-blocks (14A', 14B', 14C', and 14D');
 - each sub-block is submitted to vector quantization with a classified codebook (20), the class thereof being defined on the basis of the vector index (i) of the original block and the quadrant label (A', B', C', D') of the sub-block;
 - the vector index (j) of the sub-block with respect to this classified codebook (20) is transmitted to the receiving end;
 - at the receiving end, there is utilized a classified codebook which is chosen on the basis of the vector index (i) of the original block and the quadrant label of the sub-block;
 - at the receiving end, in the chosen classified codebook (24) that is identical with the classified codebook at the transmitting end, the said codevector is looked up on the basis of the vector index of the

transmitted sub-block, so that a reconstruction is obtained for the sub-block; and in which method, while designing each classified codebook, the utilized training image material is that part of the original training image set which belongs to the respective class, i.e. those quadrantsize sub-blocks of the training image set which receive a class index corresponding to the particular class of the codebook, when the above described method is applied to the training image set itself.

2. A method according to claim 1, characterized in that the sub-blocks are further divided into quadrants and these further into smaller and smaller sub-blocks according to the same principle, in which method each quadrant and sub-block is coded with a classified codebook, where the classifiers are the vector indices of all those parent blocks of the said quadrant or sub-block whereto the quadrant or sub-block to be coded belongs, as well as the quadrant labels of the said quadrant or sub-block as well as of the said parent blocks, and wherein the classified codebooks are designed beforehand in the above described fashion.

3. A method according to claim 1 or 2, characterized in that prior to each quadrant division of each sub-block, typical of the method, the image block is reconstructed on the basis of the information so far coded, and a difference between the image block and the reconstructed image block is created, which difference block thus contains the coding errors of the previous coding stage, and the method of the invention is applied, instead of the image block, to the thus created difference block.

4. A method according to claim 1 or 2, characterized in that at the first block level, the coding is made more effective by separating, prior to coding, the mean value of the gray level tones

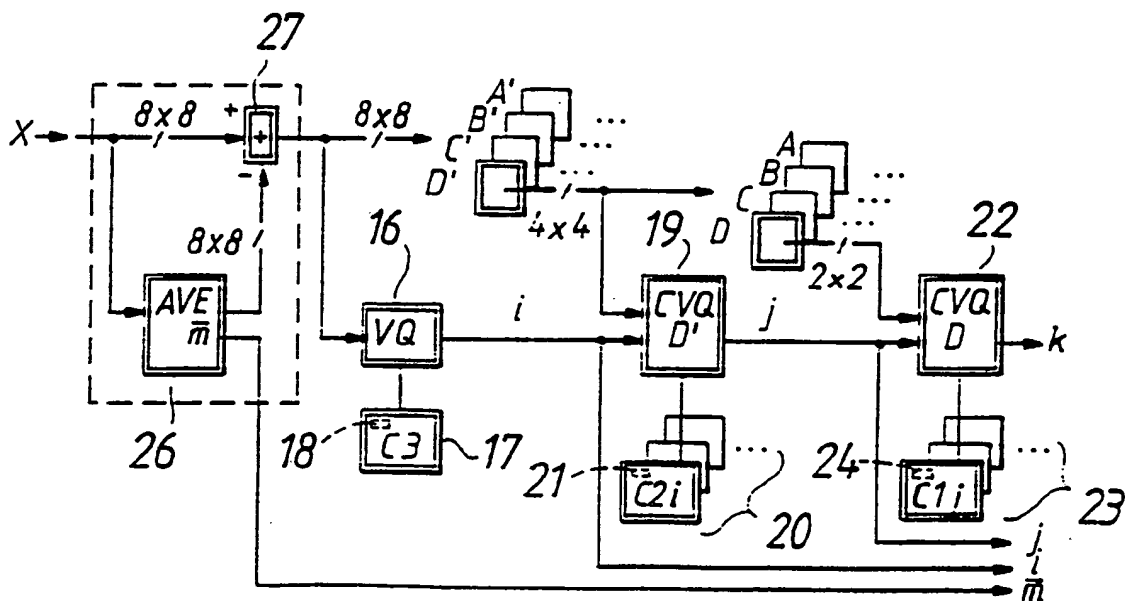
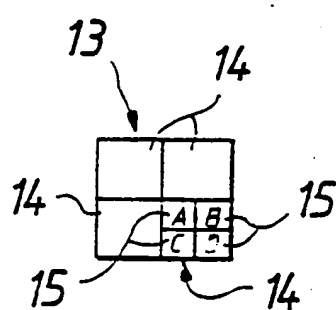
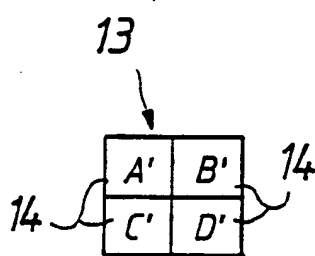
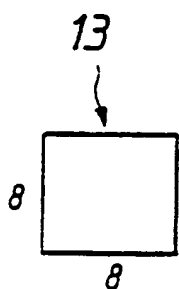
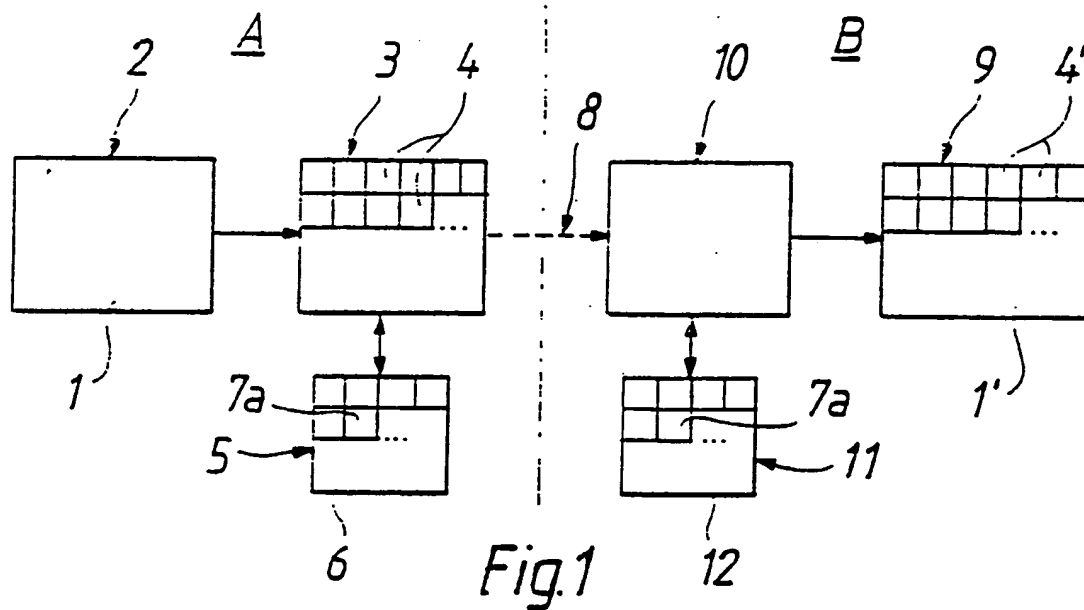
of the pixels contained in each block of the image, and by transmitting the mean value separately from the transmitting end to the receiving end.

5 5. A method according to claim 1, 2 or 3,
characterized in that the image is subjected to low pass filtering at the transmitting end, and the filtered image is separately transmitted to the receiving end, and that the method of claim 1, 2 or 3 is applied only to the high frequency component of the
10 image, i.e. to the difference image of the original and the low pass filtered image.

6. A method according to any of the claims 1 - 5, characterized in that the size of the codebooks used in coding sub-blocks and possibly subsequent smaller sub-blocks are varied case by case, on
15 the basis of the image content, so that in coding blocks with few details, there are used smaller codebooks than in coding blocks with a lot of details, and that the information of the size of the codebook is
20 transmitted as extra information.

7. A method according to any of the claims 1 - 5, characterized in that the sizes of the codebooks used in coding sub-blocks and possibly subsequent smaller sub-blocks are varied on the basis of the
25 image content of the coded block, so that in coding blocks with few details, there are used smaller codebooks than in coding blocks with a lot of details, in which case the size of the codebook is defined permanently on the basis of the class index.

1 / 2



2 / 2

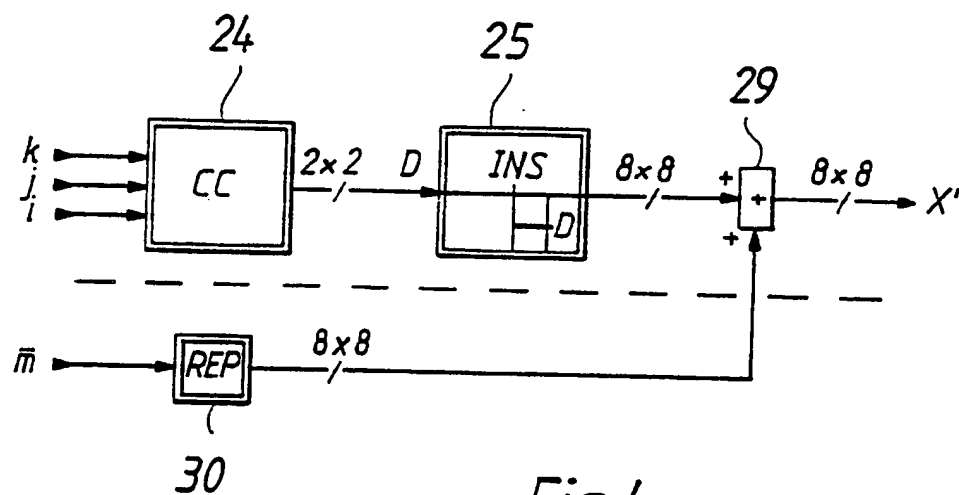


Fig 4

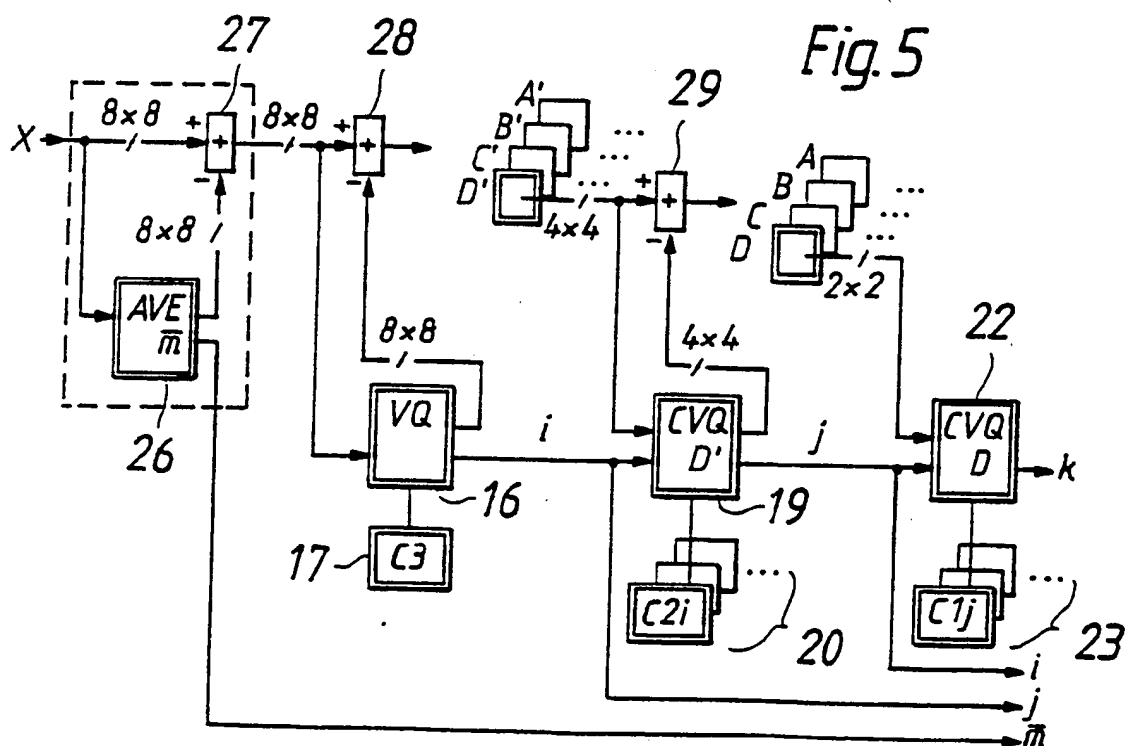


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 93/00203

A. CLASSIFICATION OF SUBJECT MATTER

IPC5: H04N 7/137

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC5: H04N, H03M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP, A2, 0280314 (FUJI PHOTO FILM CO., LTD.), 31 August 1988 (31.08.88), page 3, line 23 - page 4, line 21, figures 2,3 --	1-7
A	WO, A1, 9012460 (UTAH STATE UNIVERSITY FOUNDATION), 18 October 1990 (18.10.90), page 2, line 27 - page 6, line 25 --	1-7
A	EP, A1, 0450664 (MITSUBISHI DENKI KABUSHIKI KAISHA), 9 October 1991 (09.10.91), figures 1-8,13 --	1-7
A	EP, A2, 0433268 (MITSUBISHI DENKI KABUSHIKI KAISHA), 19 June 1991 (19.06.91), abstract --	1-7

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

8 Sept. 1993

Date of mailing of the international search report

08 -09- 1993

Name and mailing address of the ISA/
Swedish Patent Office
Box 5055, S-102 42 STOCKHOLM
Facsimile No. +46 8 666 02 86

Authorized officer

Bertil Ljungdahl
Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 93/00203

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP, A1, 0457362 (MITSUBISHI DENKI KABUSHIKI KAISHA), 21 November 1991 (21.11.91) -----	1-7

INTERNATIONAL SEARCH REPORT
Information on patent family members

30/07/93

International application No.

PCT/FI 93/00203

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP-A2-	0280314	31/08/88	JP-A- 64000881	05/01/89
			US-A- 4862261	29/08/89
WO-A1-	9012460	18/10/90	AU-A- 5526790	05/11/90
			CA-A- 2030528	07/10/90
			EP-A- 0420966	10/04/91
EP-A1-	0450664	09/10/91	CA-A- 1228163	13/10/87
			DE-A- 3485716	17/06/92
			EP-A,B- 0137314	17/04/85
			EP-A- 0446968	18/09/91
			EP-A- 0451879	16/10/91
			EP-A- 0457362	21/11/91
			JP-C- 1604969	13/05/91
			JP-B- 2029276	28/06/90
			JP-A- 60162391	24/08/85
			US-A- 4670851	02/06/87
			JP-C- 1585989	31/10/90
			JP-B- 2010634	08/03/90
			JP-A- 60177782	11/09/85
			JP-A- 60194686	03/10/85
			JP-C- 1600133	31/01/91
			JP-B- 2025598	04/06/90
			JP-A- 60055790	01/04/85
EP-A2-	0433268	19/06/91	AU-B- 579452	24/11/88
			AU-B- 587954	31/08/89
			AU-A- 2216988	15/12/88
			AU-A- 5415386	04/09/86
			DE-A- 3685238	17/06/92
			EP-A,B- 0193185	03/09/86
			JP-A- 61205093	11/09/86
			US-A- 4710812	01/12/87
			JP-A- 61230586	14/10/86
			JP-C- 1660724	21/04/92
			JP-B- 3024102	02/04/91
			JP-A- 61237519	22/10/86
			JP-B- 4073839	24/11/92
			JP-A- 62076992	09/04/87

INTERNATIONAL SEARCH REPORT
Information on patent family members

30/07/93

International application No.
PCT/FI 93/00203

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A1- 0457362	21/11/91	CA-A- 1228163	13/10/87
		DE-A- 3485716	17/06/92
		EP-A,B- 0137314	17/04/85
		EP-A- 0446968	18/09/91
		EP-A- 0450664	09/10/91
		EP-A- 0451879	16/10/91
		JP-C- 1604969	13/05/91
		JP-B- 2029276	28/06/90
		JP-A- 60162391	24/08/85
		US-A- 4670851	02/06/87
		JP-C- 1585989	31/10/90
		JP-B- 2010634	08/03/90
		JP-A- 60177782	11/09/85
		JP-A- 60194686	03/10/85
		JP-C- 1600133	31/01/91
		JP-B- 2025598	04/06/90
		JP-A- 60055790	01/04/85